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GENETIC VARIABILITY FOR GRAIN IRON, ZINC, OTHER NUTRIENTS AND YIELD RELATED TRAITS IN SORGHUM (*Sorghum bicolor* (L.) Moench)

CH. SUSMITA[1] & B. SELVI[2]

Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

ABSTRACT

Micronutrient malnutrition resulting from dietary deficiency of iron (Fe), zinc (Zn) and other essential nutrients, is a wide spread food-related health problem globally. Diversified food and cultivars with elevated levels of nutrients provide most cost effective solution for this alarming problem. The success of an effective breeding programme and the genetic improvement of any crop species depend upon the nature of genetic variability present in the population. Knowledge on relative magnitude of variability present in the crop species is most important as it forms basis of selection and thus enables execution of any crop improvement programme. Hence, the present investigation was undertaken to determine the magnitude of genetic variability for grain iron and zinc content and other quantitative and nutritional traits in diverse range of breeding materials. A wide range of variability existed for all the traits studied indicating the presence of significant variation among the genotypes. High PCV and GCV estimates revealed the extent of variability and high heritability coupled with high genetic advance recorded for all the traits except total magnesium indicated that these traits respond to selection. The genetic variability found among the 58 sorghum genotypes for six nutritional traits can be exploited in the breeding programme for producing nutrient dense genotypes.

KEYWORDS: Malnutrition, Variability, Nutrients, Selection, Heritability, Genetic Advance

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important cereal crop globally and is the dietary staple of more than 500 million people in over 90 countries (Reddy *et al.*, 2010). It is the third most important food crop in India after rice and wheat and second cheapest source of energy and micronutrients, after pearl millet (*Pennisetum glaucum*) with a vast majority of the population in Africa and Central India depending for their dietary energy and micronutrient requirements (Rao *et al.*, 2006).

Iron (Fe) and zinc (Zn) were the two micronutrients recognized by WHO of the United Nations as limiting as they are the chief factors responsible for malnutrition among people living in arid and semi-arid regions. These two micronutrients are considered to be very essential components of human diet since they have several functions in the human body and in turn deficiency of these micronutrients lead to severe consequences with great impact on health and also on economic development of countries (Hunt *et al.*, 2005). Sorghum owing to its importance as a drought tolerant crop also supplies important minerals, vitamins, protein and micronutrients essential for optimal health, growth and development of humans (Chan *et al.*, 2007). Hence, concentration should be laid on methods involved in determination of nutritional composition in sorghum which is of paramount significance for eradicating malnutrition caused by lack of mineral nutrients. Breeding for higher concentration of minerals in food crops is an alternative method for improving the health of humans suffering from the consequences of mineral deficiency (Feil*et al.*, 2005).

Identifying and manipulating the available germplasm accessions can improve yield and quality of sorghum varieties. Therefore exploitation of available genetic variation for nutritional composition requires the identification of superior sorghum accessions in terms of yield and quality before inclusion in sorghum breeding programme.

MATERIALS AND METHODS

An experiment was conducted at Department of millets, Tamil Nadu Agricultural University, Coimbatore with the breeding material comprising of 58 diverse sorghum genotypes. These lines include seventeen varieties, twenty two R lines and nineteen B lines collected from different sources. The study was conducted at research farm of TNAU, Coimbatore ($8^{o}5^{1}$ and $13^{o}35^{1}$ N and $76^{o}14^{1}$ and $80^{o}21^{1}$ E) during the year 2012-13 *kharif* season. The genotypes were evaluated in randomized block design (RBD) with two replications following all agronomic practices. In each row five uniformly looking panicles were bagged with kraft paper bags prior to flowering in each replication to avoid pollen contamination and to harvest pure seed for assessing the nutrition content. After threshing, cleaning and weighing, the grains from each entry were dried in hot air oven at 60^{0} C for 6 hours and then ground in Wiley Mill separately, labelled properly and stored in air tight container for further analysis. Observations were recorded on days to 50 % flowering, days to maturity, plant height(cm), panicle length (cm), panicle width (cm), panicle weight (g), 100 grain weight (g), total iron (mg/ kg), total zinc (mg/kg), total calcium (mg/ 100g), total magnesium (mg/ 100g), crude protein (%), crude fat (%), biomass yield (g) and grain yield per plant (g). Except days to 50 % flowering, all the remaining parameters were recorded at maturity.

Preparation of Triple Acid Extract and Estimation of Mineral Elements

A known weight of powdered (1.0 g) grain sample was digested with 12 ml of triple acid (Nitric acid, Sulphuric acid, Perchloric acid in the ratio of 9:2:1). The triple acid extract was subjected for iron and zinc estimation and the absorbance wasrecorded at 248.33 nm and 213.86 nm respectively in Atomic Absorption Spectrophotometer (AAS) by following the procedure of (Jackson, 1973) and result expressed in mg kg^{-1} sample. Total calcium was estimated by following Versenate titration method as suggested by (Jackson, 1973) by using murexide indicator in the presence of sodium hydroxide buffer and total magnesium was estimated by using EBT indicator in the presence of ammonium hydroxide - ammonium chloride buffer and expressed in mg $100g^{-1}$ of sample.

Estimation of Crude Protein and Fat

A known weight of (0.5g) of the powdered sample was treated with diacid mixture (Sulphuric and Perchloric acid in the ratio 5:2). The total nitrogen content was estimated by conventional Micro-Kjeldahl method (Humphries, 1956) and the estimated value was multiplied by 6.25 to obtain the crude protein per cent. Crude fat was estimated by subjecting a known weight (2g) of the grain sample to continuous extraction with petroleum ether in a Soxhlet apparatus.

Statistical Data Analysis

Data obtained was subjected to analysis of variance (ANOVA) using the GENSTAT 9.1 package to assess the significant differences among the genotypes for mean performance. The data was analyzed statistically for estimating variability parameters like genotype and phenotype coefficients of variation (Burton, 1952), heritability (Allard, 1960) and genetic advance (Johnson *et al.*, 1955).

RESULTS AND DISCUSSIONS

Analysis of variance for the fifteen characters (Table 1) revealed highly significant differences between the genotypes for all the characters studied in the present investigation. The mean performance of fifty eight sorghum genotypes for fifteen characters is presented in Tables 2 and 3.

Table 1: Analysis of Variance for Fifteen Characters in 58 Genotypes of Sorghum

SL. No		Mean Sum of Squares		
		Replication (1)	**Treatment (57)**	**Error (57)**
1	Days to 50 per cent flowering	0.03	6.10**	1.20
	Days to maturity	6.75	187.35**	0.58
2	Plant height (cm)	11.42	1865.10**	23.89
	Panicle length (cm)	5.60	56.73**	2.08
3	Panicle girth (cm)	0.25	12.24**	0.25
	Panicle weight (g)	229.18	452.65**	43.45
4	100 Grain weight (g)	0.01	0.19**	0.001
	Total iron (mg kg^{-1})	24.49	50.41**	1.09
5	Total zinc (mg kg^{-1})	0.75	53.37**	0.94
	Total calcium (mg $100g^{-1}$)	2.20	63.16**	2.20
6	Total magnesium (mg $100g^{-1}$)	13.58	190.61**	1.20
	Crude protein (per cent)	1.62	332.23**	0.09
7	Crude fat (per cent)	0.10	64.36**	0.36
	Biomass yield (g per plant)	91.20	774.64**	71.97
8	Grain yield per plant (g)	183.58	452.62**	36.03
9				

Values bolded in the parenthesis represent degrees of freedom
*Significant at 5% level
**Significant at 1% level

Mean Performance of Morphological Traits

In plant breeding programmes, one of the simplest selection criteria for identification of superior genotypes is *Per se* performance of the parents. The genotypes with high *per se* performance would be much useful as parents which are capable of producing better off springs (Rai *et al.*, 2009). Parents with significant *per se* performance are expected to yield superior recombinants in the segregating generations. Hence, it is worthwhile using them in hybrid breeding programmes which would yield good hybrids for the desired traits that are ought to be improved.

Table 2: Mean Performance of 58 Genotypes for Yield and Yield Related Traits in Sorghum

S. No	Genotypes	Plant Height (Cm)	Days to 50% Flowering	Days to Maturity	Panicle Length (Cm)	Panicle Width (Cm)	Panicle Weight (G)	100 Seed Weight (G)	Biomass Yield (G)	Grain Yield/ Plant (G)
1	TNS 643	199.00	57.50*	97.00	22.70	15.95*	75.12*	3.16*	126.00*	55.60*
2	Co 18	160.50*	63.00	102.50	15.00	15.10*	47.66	2.48	114.00	35.18
3	Co 22	149.45*	52.00*	91.00	22.10	13.05	63.15	2.36	119.25	49.50
4	SPV 1431	181.25	54.50*	74.50*	12.80	13.05	23.88	2.81	**64.45**	**15.73**
5	SPV 527	178.75	52.50*	74.50*	**9.80**	14.20*	**22.75**	2.34	100.00	17.32
6	K 3	162.25	60.50	92.50	12.10	13.25	45.00	3.17*	89.40	33.78
7	K4	226.25	63.00	102.50	26.30	11.70	37.00	2.89	101.10	32.21
8	SPV 351	219.25	55.00*	80.00	12.10	12.00	22.90	2.51	88.25	17.70
9	K 7	182.50	56.00*	74.50*	28.70*	9.20	43.25	2.39	81.00	24.20
10	K 8	155.25	**70.50**	95.50	25.70	14.90*	54.70	3.29*	122.15	33.35
11	LOCAL 1	178.50	60.50	92.50	24.70	9.00	48.60	3.08*	94.80	47.68
12	TNAU 1	**235.25**	67.00	93.00	25.90	6.75	36.00	2.49	108.10	23.75
13	TNAU 2	226.00	63.00	93.50	27.40*	**6.15**	43.00	2.72	65.45	61.17*
14	APK 1	147.50*	62.50	94.00	28.60*	14.75*	**84.00***	3.21*	112.26	43.21
15	Co 28	175.00	60.50	74.00*	28.70*	17.80*	76.60*	3.16*	122.11	56.66*

16	CSV 17	107.50*	59.50	93.00	21.50	13.40	53.00	3.12*	99.45	43.08
17	TNS 30	143.25	63.50	93.50	29.30	14.45	77.00*	3.38*	125.05	59.16
18	Co 30	164.75	61.00	74.00*	21.60	16.25*	77.20*	3.29*	107.50	56.27*
19	TNS 641	200.00	56.50*	96.50	25.55	15.40*	64.90	3.14*	131.45*	56.68*
20	TNS 638	176.25	60.50	82.00*	24.15	12.65	80.40*	3.31*	91.45	52.18*
21	TNS 640	184.50	61.00	96.50	24.00	14.80*	70.41	3.35*	124.50*	60.40*
22	TNS 639	177.00	61.00	97.00	23.40	14.40*	82.75*	3.11*	111.50	**69.45***
23	TNS 637	176.75	61.00	90.50*	21.60	12.20	73.35*	2.76	132.90*	60.54*
24	TNS 636	177.00	59.50	90.00*	19.90	9.00	49.20	2.68	119.50	36.93

Table 2: Contd.,

25	TNS 635	178.25	60.50	90.50*	25.10	12.50	57.00	3.06*	95.55	42.28
26	TNS 634	184.50	57.00*	90.50*	22.60	12.20	49.05	3.01*	81.25	38.04
27	TNS 633	182.50	60.00	90.50*	27.00	13.20*	54.50	2.81	94.50	31.27
28	TNS 632	182.00	55.00*	97.00	24.05	15.90*	45.00	2.94	107.65	28.58
29	TNS 631	181.25	57.00*	96.50	27.25*	14.65*	64.31	2.87	96.23	55.46*
30	TNS 630	185.75	55.00*	96.50	21.95	11.60	52.50	2.81	82.76	43.40
31	TNS 629	173.25	59.50	96.50	23.20	11.90	66.50	2.61	105.96	48.66
32	TNS 628	190.50	60.50	96.50	25.80	16.35*	77.00*	2.90	124.90*	63.18*
33	TNS 627	180.50	60.00	96.50	23.75	14.50*	80.29*	2.87	134.55*	65.58*
34	TNS 623	172.00	55.00*	96.50	23.35	13.80	45.50	2.51	137.25*	34.05
35	TNS 618	199.25	60.00	82.00*	19.50	15.70*	54.50	2.59	128.70*	44.92
36	TNS 642	187.50	55.50*	83.00*	19.80	11.95	62.22	3.27*	102.00	55.22*
37	TNS 644	179.25	56.50*	95.50	25.90	12.85	48.50	2.83	122.00	37.01
38	TNS 645	170.75	62.00	83.00*	23.30	11.95	46.50	2.75	124.15*	47.46
39	ICS 29016B	152.00*	68.00	109.50	31.30*	11.20	43.81	3.28*	**143.50***	34.61
40	ICS 29015B	127.00*	55.00*	102.50	30.60*	12.45	61.00	3.15*	124.60*	45.96
41	ICS 29014B	152.25*	69.00	**112.50**	25.00	13.85	55.00	2.89	120.10	37.81
42	ICS 29013B	151.25*	68.00	109.50	23.35	12.90	52.50	2.51	108.70	32.95
43	ICS 29012B	137.50*	57.50*	99.50	17.20	14.50*	56.10	**3.40***	121.00	37.85
44	ICS 29011B	153.00*	60.00	109.50	26.80	11.55	58.50	2.95	139.00*	32.79
45	ICS 29010B	126.25*	**50.50***	99.50	28.30*	14.20*	56.50	3.09*	91.65	51.88*
46	ICS 29009B	159.00*	55.50*	96.50	**37.80***	10.95	74.50*	3.21*	122.36	46.41
47	ICS 29008B	154.75	56.50*	96.50	33.95*	12.35	67.75	**1.87**	114.25	44.67
48	PBT 30377B	112.50*	54.50*	99.00	25.10	14.30*	58.50	3.26*	126.00*	54.11
49	PBT 30376B	107.00*	54.00*	98.50	24.50	**18.30***	41.12	2.68	111.10	61.32*
50	PBT 30351B	145.75*	66.50	98.50	26.80	15.55*	68.10	2.88	109.60	53.22*
51	PBT 30319B	134.00*	59.50	98.50	26.80	9.30	67.43	2.93	102.00	57.29*
52	ICS 2219B	**104.25***	60.50	88.00*	16.60	12.75	47.71	2.70	99.10	33.73
53	ICS 51B	138.50*	57.50*	80.50*	25.20	7.01	44.55	3.22*	121.15	33.11
54	Co 26	168.10	61.00	75.00*	20.20	12.90	73.38*	3.06*	88.70	62.73*
55	ICS 21B	117.25*	56.50*	80.50*	30.50*	14.10*	69.60	2.69	65.80	52.28*
56	ABT 1002B	133.00*	58.50*	**72.50***	31.40*	13.95*	49.75	2.85	77.75	40.40
57	ABT 1024B	120.50*	57.50*	82.50*	30.70*	12.00	61.75	3.04*	68.45	43.85
58	ICS 29006B	114.00*	57.00*	99.50	26.30	14.60*	75.18*	2.99*	90.00	44.67
	Mean	164.46	59.28	92.09	24.22	13.05	57.55	2.91	107.48	44.46
	S.E.	3.45	1.60	0.54	1.02	0.35	6.59	0.02	8.48	2.65
	C.D at 5 %	9.78	0.07	2.20	2.89	1.01	13.19	0.07	16.98	6.31

***Higher than the General Mean**

When cultivars with different maturity groups will be grown in an area, pests such as shoot fly, stem borer, aphids, midge etc. are likely to infest late maturing cultivars (Rao *et al*., 2006). The genotypes which flowered earlier results in early maturity which helps to escape drought, incidence of pests and diseases and other undesirable factors. The general mean was 59.28. Twenty six genotypes were found earlier than the general mean.

Highest panicle length of 37.80 cm and panicle width of 18.30 cm was recorded. Eleven genotypes had significantly surpassed the grand mean of 24.22 cm for panicle length.The general mean for panicle width was 13.05 cm and twenty two genotypes significantly reported higher value than the general mean. With respect to breeding for grain yield panicle weight has direct contribution for yield improvement. Twelve genotypes had significantly exceeded the general mean of 55.50 g.

Highest 100 grain weight of 3.40 g was recorded in the present investigation. General mean for the trait was 2.91 g and twenty nine genotypes had significantly higher values than the general mean.Biomass yield is one of the most

important objectives of forage breeding. High plant stature contributes to fodder yield. The general mean was 107.48 g per plant. Twenty four genotypes surpassed the grand mean. Grain yield had reported a variability of 69.45-15.73 g. The general mean was 44.46 g and twenty four genotypes significantly exceeded the general mean.

Mean Perforance of Nutritional Traits

Improvement of nutritional quality is presently being emphasized and desirable progress has been made towards genetic improvement of micronutrients especially iron and zinc. The need for genetic improvement of nutritional quality of sorghum is emphasized by the fact that this crop is grown in arid regions where populations face severe malnutrition (Mathur and Mathur, 1986). The mean value for grain total iron content ranged from 21.35 mg kg^{-1} to 44.55 mg kg^{-1}. The general mean accounted to 36.56 mg kg^{-1} and twenty four genotypes were found to excel the general mean significantly. Total zinc content varied from 11.33 mg kg^{-1} to 33.18 mg kg^{-1}. The general mean was 23.02 mg kg^{-1}. Seventeen genotypes showed significantly higher than the general mean.

Calcium is essential for the development of strong bones and teeth. Low bioavailability of calcium frequently induces bone mineral pathologies in populations dependent upon cereal grains as a staple food. The range of total calcium varied from 12.00 mg $100g^{-1}$ to 32.60 mg $100g^{-1}$. The general mean was 22.45 g $100g^{-1}$ and eighteen genotypes expressed significantly greater values than the general mean. Magnesium helps the body to process fat and protein, and is important for the secretion of parathyroid hormones. Magnesium plays an important role in regulating blood pressure. The total magnesium content of selected sorghum genotypes ranged from 93.85 mg $100g^{-1}$ to 138.55 mg $100g^{-1}$. General mean was 109.70 mg $100g^{-1}$ and twenty two genotypes exceeded the general mean significantly.

Cereals provide a second source of protein in diet, which, are partially incomplete protein (Fleck, 1981). There is possibility of improving sorghum cultivars, which are nutritionally superior with respect to protein content (Dodiya and Joshi, 2003). Protein content ranged from 7.10 per cent to 14.57 per cent respectively. The general mean accounted for 10.95 per cent and twenty five were found to excel the grand mean significantly.

Table 3: Mean Performance of 58 Genotypes for Nutritional Traits in Sorghum

Sl. No	Genotypes	Total Iron(Mg/Kg)	Total Magnesum (Mg/Kg)	Total Calcium (Mg/100g)	Total Magnesium (Mg/100g)	Crude Protein (%)	Crude Fat (%)
1	TNS 643	41.90*	23.54	14.00	114.40*	10.50	3.25*
2	Co 18	32.56	23.95	29.20*	111.50	9.52	2.18
3	Co 22	34.90	20.84	21.07	121.55*	10.73	1.52
4	SPV 1431	37.85	21.07	21.50	97.35	12.26*	3.13*
5	SPV 527	26.35	13.18	19.20	121.85*	12.37*	3.13*
6	K 3	42.85*	29.29*	23.00	101.55	11.62*	3.05*
7	K4	33.05	20.97	27.20*	111.80	12.48*	2.59
8	SPV 351	29.25	18.41	23.00	106.30	7.77	2.40
9	K 7	27.35	13.29	25.00	99.70	9.24	2.26
10	K 8	32.45	21.96	24.50	121.05*	12.19*	2.77
11	LOCAL 1	29.71	13.67	17.00	116.05*	11.79*	3.91*
12	TNAU 1	37.45	22.87	23.20	114.65*	12.00*	2.50
13	TNAU 2	29.90	18.67	29.00*	97.05	8.78	2.77
14	APK 1	42.65*	31.24*	31.50*	111.85	7.18	3.18*
15	Co 28	35.15	21.11	28.00*	123.85*	10.49	3.93*
16	CSV 17	41.85*	27.88*	20.40	114.40*	13.24*	3.42*
17	TNS 30	40.55*	22.38	31.00*	111.15	12.01*	3.10*
18	Co 30	43.45*	30.98*	**32.60***	121.25*	**7.10**	3.13*
19	TNS 641	39.10*	17.81	19.00	97.60	11.94*	3.58*
20	TNS 638	37.25	18.86	28.40*	108.35	12.29*	2.57

21	TNS 640	34.80	20.81	17.00	95.40	12.22*	2.74
22	TNS 639	40.05*	23.82	24.00	99.05	8.68	2.82
23	TNS 637	40.50*	22.27	17.30	126.30*	10.09	3.52
24	TNS 636	39.35*	23.08	22.00	96.25	10.48	2.52
25	TNS 635	43.55*	**33.18***	13.20	107.45	11.03	2.66
26	TNS 634	35.70	19.83	16.00	102.65	9.14	3.01*
27	TNS 633	32.10	20.56	24.20	114.40*	9.35	2.83*
28	TNS 632	33.65	22.18	17.00	**93.85**	8.81	3.31*
29	TNS 631	32.55	21.14	15.00	109.05	12.43*	2.96*

Table 3: Contd.,

30	TNS 630	37.10	21.06	26.30*	116.40*	10.50	3.20*
31	TNS 629	42.55*	29.03*	21.00	104.75	11.30	2.57
32	TNS 628	41.38*	27.13*	23.10	107.70	10.23	3.57*
33	TNS 627	31.40	21.15	13.50	98.90	8.92	2.99*
34	TNS 623	41.00*	25.65*	15.20	95.55	11.70*	4.22*
35	TNS 618	41.75*	29.83*	18.00	111.55	11.51	2.31
36	TNS 642	39.40*	31.74*	17.50	95.15	9.31	3.21*
37	TNS 644	37.50	23.52	13.00	121.55*	12.01*	2.11
38	TNS 645	34.00	23.93	21.60	98.95	13.89*	**1.10**
39	ICS 29016B	38.70*	26.20*	23.52	113.15*	10.30	3.55*
40	ICS 29015B	28.10	13.72	31.40*	119.55*	12.93*	1.91
41	ICS 29014B	31.90	17.44	23.00	104.70	11.91*	1.37
42	ICS 29013B	**21.35**	**11.33**	17.44	109.70	10.80	2.15
43	ICS 29012B	33.90	25.67*	18.00	105.50	9.93	2.47
44	ICS 29011B	35.05	17.13	**12.00**	114.15*	11.27	1.84
45	ICS 29010B	38.70*	23.59	21.00	115.05*	10.96*	2.58
46	ICS 29009B	36.95	23.97	19.70	121.85*	7.43	**4.57***
47	ICS 29008B	35.90	20.87	19.00	101.35	**14.57***	3.70*
48	ICS 29006B	38.90*	21.98	31.30*	103.65	11.13	2.86
50	PBT 30376B	**44.55***	29.14*	29.10*	**138.55***	12.72*	2.04
51	PBT 30351B	40.75*	31.08*	29.40*	100.90	13.23*	1.68
52	PBT 30319B	42.00*	30.62*	30.00*	116.75*	14.28*	2.62
53	ICS 2219B	35.90	23.41	28.00*	101.10	11.55	1.34
54	ICS 51B	32.40	15.19	31.20*	105.25	10.69	3.16*
55	Co 26	37.15	26.10*	23.00*	119.65*	10.82	2.28
56	ICS 21B	31.75	22.25	21.50	111.70	12.29*	2.67
57	ABT 1002B	41.85*	28.32*	31.00*	102.40	10.66	1.49
58	ABT 1024B	42.25*	29.65*	26.00*	113.35*	11.98*	1.95
	Mean	36.56	23.02	22.45	109.70	10.95	2.71
	S.E.	0.73	0.68	1.05	0.77	0.22	0.05
	C.D at 5 %	2.08	1.94	2.97	2.19	0.62	0.16

*** Higher than the General Mean**

The flour quality of sorghum depends upon the fat content. High fat content results in poor storability and odour during storage and makes it unsuitable for human consumption. So genotypes with low fat content could be desirable attribute for consumption. Genotypes with low fat content (2.5 to 3.0 per cent) were found to be promising for this trait. The range observed for crude fat varied from 1.10 percent to 4.57 per cent. Twenty three genotypes had significantly surpassed the grand mean of 2.71 percen**t.**

Genetic Variability Studies

Genetic improvement in the crops depends on heritability and magnitude of variation of characters of economic importance. Hence, knowledge about the variability of genotypes can be assessed using parameters like genetic coefficient of variation, heritability and genetic advance is of paramount significance for initiating an efficient breeding programme in sorghum. The parameters like, genotypic variance and genetic advance for various characters were expressed in their respective units and standard unit less measures like phenotypic coefficient of variation, genotypic coefficient of variation and environment coefficient of variation were also being calculated. It is necessary to give due consideration for phenotypic and genotypic coefficient of variation, heritability and genetic advance as percent of mean for better understanding of the variability.

In the present study, based on results of analysis of variance it can be concluded that significant genotypic differences was present among the 58 genotypes for the fifteen characters justifying further analysis. The significant difference could also be attributed to the compositions of the population, which is made of diverse genotypes. It was evident from the range of values obtained for different characters that high phenotypic variability encompasses genotypic, environmental and genotype × environmental interaction components. In this study, the values of phenotypic variance exceeded genotypic variance for almost all the characters except for the trait 100 grain weight for which phenotypic variance is almost equal to genotypic variance indicating that except 100 grain weight all other traits are considerably influenced by environment.

High GCV and PCV estimates were recorded for grain yield per plant followed by crude fat, panicle weight, total calcium, total zinc and panicle length (Table 4). Panicle width, biomass yield, plant height, crude protein and total iron had moderate PCV and GCV. Low GCV and PCV estimates were recorded for 100 grain weight, days to maturity, total magnesium and days to 50 per cent flowering. Similar findings were reported in the earlier studies for the above characters (Chavan *et al.,* 2010). The genotypic and phenotypic coefficient of variation indicated the extent of variability for different traits. For assessing the heritable variation, the magnitude of heritability is the most important aspect in the breeding material, which has close bearing on the response to selection with fixable additive gene action. The high heritability in broad sense recorded for all the characters studied, indicating that genotype plays a most important role than environment in determining the phenotype. Similar results have been reported by (Tiwari *et al.*, 2003).

The advance in the mean value of population as a result of selection depends on (1) heritability of the trait (2) phenotypic variation (3) selection pressure. Even the traits that recorded 100 per cent heritability may express little genetic advance when there is little genotypic variation. The information on heritability solely may not help in pin pointing characters for enforcing selection. Nevertheless, the heritability estimates in conjunction with predicted genetic advance will be more reliable (Johnson *et al.,* 1955). Heritability gives the information on the magnitude of inheritance of traits, while genetic advance will be helpful in formulating suitable selection procedures.High heritability combined with high genetic advance was observed for all the traits except days to 50 per cent flowering and total magnesium which had high heritability but moderate genetic advance. This indicates that all the traits other than days to 50 per cent flowering and total magnesium would respond to selection and are found to be predominantlygoverned by additive gene action and therefore selection would be effective for improving the traits. Similar results were obtained by Bapat and Shinde (1980).

Table 4: Estimates of Variability and Genetic Parameters for Fifteen Characters of Sorghum

S. No	Characters	Mean	Variance		Pcv %	Gcv %	H^2	Ga	Ga as % Mean
			Pv	Gv					
1	Plant height (cm)	164.46	**944.49**	**920.60**	18.68	18.44	97.50	**61.70**	37.52
2	Days to 50 % flowering	59.28	18.65	17.44	**7.28**	**7.04**	93.50	8.32	**14.03**
3	Days to maturity	92.09	93.96	93.38	10.52	10.49	**99.40**	19.84	21.55
4	Panicle length (cm)	24.22	29.41	27.32	22.39	21.58	92.90	10.38	42.86
5	Panicle width (cm)	13.05	6.25	5.99	19.15	18.75	95.90	4.93	37.83
6	Panicle weight (g)	57.55	248.04	204.60	27.37	24.85	82.48	26.76	46.50
7	100 Seed weight (g)	2.91	**0.10**	**0.09**	10.85	10.77	98.50	**0.64**	22.03
8	Total iron (mg kg^{-1})	36.56	25.75	24.66	13.88	13.58	95.80	10.01	27.38
9	Total zinc (mg kg^{-1})	23.02	27.16	26.21	22.63	22.24	96.50	10.36	45.01
10	Total calcium (mg/ 100g)	22.45	32.68	30.48	25.46	24.59	93.20	10.98	48.92
11	Total magnesium (mg/100g)	109.70	95.90	94.70	8.92	8.87	98.70	19.92	18.15

12	Crude protein (%)	10.95	2.96	2.86	15.71	15.45	96.70	3.42	31.29
13	Crude fat (%)	2.71	0.56	0.51	27.74	27.58	98.90	1.53	56.50
14	Biomass yield (g/plant)	107.48	**423.31**	**351.33**	19.14	17.44	**82.99**	35.18	32.73
15	Grain yield per plant (g)	44.46	168.93	161.87	**29.24**	**28.62**	95.82	25.66	**57.71**

Values bolded were highest and lowest mean values

PV- Phenotypic Variance GV- Genotypic Variance

PCV- Phenotypic Coefficient of Variation GCV- Genotypic Coefficient of Variation

GA- Genetic Advance

CONCLUSIONS

In the current study it is clear that large genotypic variability existing in the genotypes for nutritional and yield related traits is encouraging for selecting potential genotypes as parents for future breeding programme. High GCV and PCV estimates were recorded for grain yield per plant followed by crude fat, panicle weight, total calcium, total zinc and panicle length. Most of the traits exhibited low differences between their genotypic coefficient of variation and phenotypic coefficient of variation indicating low influence of environment. High heritability coupled with high genetic advance as percentage of mean was observed for plant height, biomass yield, days to maturity, panicle length, panicle width, panicle weight, 100 grain weight, total iron, total zinc, total calcium, crude protein and crude fat. These characters need to be given more importance in selection as these traits were governed by additive genes and hence respond to selection.

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